

# CASE STUDY OF THE 20 MAY 2008 TORNADIC STORM IN HUNGARY

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## Abstract

A case study was performed to investigate a tornadic thunderstorm, which occurred on 20 May 2008 over Hungary. The synoptic situation was analysed. The paper is focused on remote sensing measurements: METEOSAT single channel data, different types of RGBs together with Hungarian radar network data, and lightning data from the SAFIR detection system were used. First, we have analysed satellite and radar imagery separately; then satellite, radar and lightning data together. In METEOSAT imagery we analysed both the high-level cloud top characteristics, and the low-level features. By the analysis of the cloud top characteristics, we found cold ring and cold U shapes in IR images; as well as strong overshooting tops, plumes, radial cirrus, gravity waves in several visible images. The cloud top microphysics were investigated both qualitatively and quantitatively. The imagery showed many small ice crystals on the cloud tops, referring to a high probability of strong updraft. By the analysis of the visible images at the early life cycle of the storm we have found some low-level features, which might also refer to the severe nature of the system. On some radar images bow echo features were observed, which often refer to severe storm. At last we have analysed the satellite, radar and lightning data together. We have visualized them jointly to see the relative locations of the different features.

## INTRODUCTION

On 20 May 2008 a severe storm system developed over Hungary causing heavy precipitation, strong winds and hail (2-5 cm). Tornado, funnel clouds were reported. Flash floods occurred at some places. A fishing lake damn broke causing additional floods on the surrounding area. The storm system was developing fast. Late afternoon it spread to Romania causing hail, flash floods and damages at several places as well.

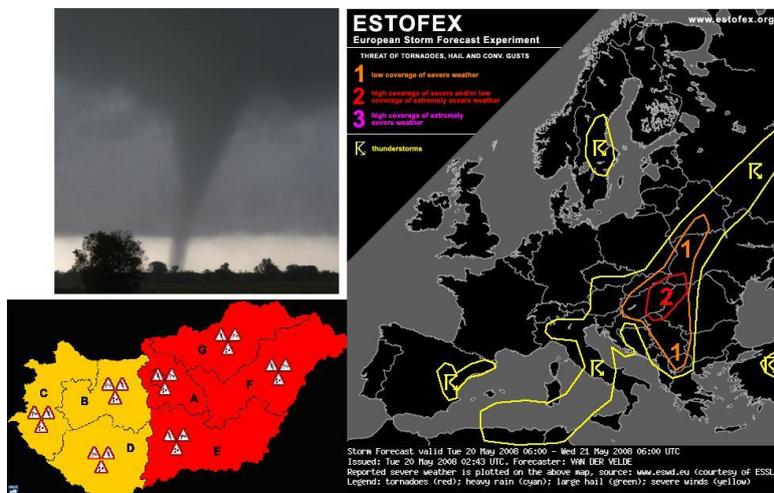


Figure 1: Tornado photo taken by a 'storm-chaser group' on 20 May 2008 at 13:50 UTC near village Gátér (upper left), warning map for Hungary given on 20 May 2008 at 13:00 UTC (bottom left) and Estofex forecast given at 12 UTC (right).

The Hungarian Meteorological Service gave the highest alarm the day before, forecasting even possible tornados (Fig. 1). MeteoAlarm (Alerting Europe for Extreme Weather) and Estofex (European Storm Forecast Experiment) homepages gave also high alarm for Hungary.

## SYNOPTIC SITUATION

Several low-pressure areas can be found on the surface analysis of May 20, the main one centered over Italy, a weak one over Scandinavia, and there is an Atlantic low far away from the continent. A weak ridge stretches from Iceland via the UK towards Portugal. The most interesting is the Mediterranean low with its extension over the Balkan filled with an unstably stratified airmass with predicted MLCAPE values in the 500-1500 J/kg range. To the south-east of an elongated stationary occlusion over Russia/southeast Belarus towards Slovakia and Slovenia thunderstorms will concentrate near zones of enhanced low-level convergence. Over this zone, a south-westerly mid level flow creates locally moderate deep layer shear, especially over the Balkan where warm air advection creates veering winds with height favorable for the formation of supercell and long-lived multicell clusters. (The ESTOFEX forecast, airmass RGB imagery and surface chart (Fig.2) were used for the synoptic situation analysis.)

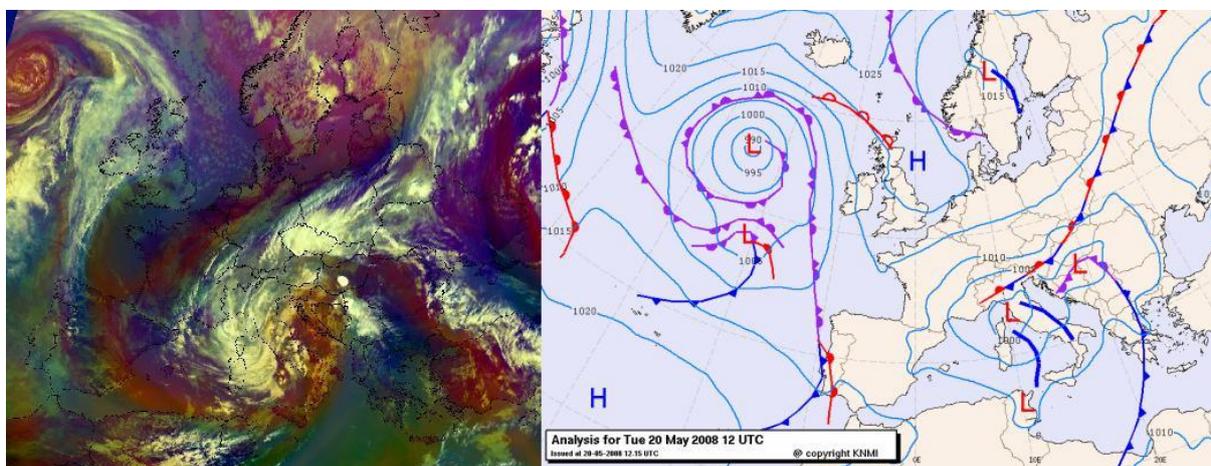


Figure 2: Airmass RGB (WV6.2-WV7.3,IR9.7-IR10.8,WV6.2i) on 20 May 2008 at 11:40 UTC (left), and KNMI surface chart for 20 May 2008 12 UTC (right).

## SUMMARY OF THE SATELLITE-RELATED INDICATORS FOR POSSIBLE SEVERE WEATHER ON 20 MAY 2008

The 20 May 2008 severe weather case was not only a cold ring-shape storm, but there was a large number of indicators for severe weather: All these indicators together mean very likely severe storm.

- cold ring-shape storms
- unstable environment (GII product)
- explosive growth
- cold tops
- strong overshooting
- long-living (more than 10 hours)
- right-moving
- plume (on HRV images)
- small ice (on RGB images)
- strong updrafts (on T-Reff plots)
- low-level inflow jet (on HRV images)

Some of these features are seen in animations. At the time of this case the rapid scanning was on. Rapid scan images, animations provide excellent tool to investigate severe storms.

## GLOBAL INSTABILITY INDEX

Global Instability Index products calculated in full resolution showed unstable situation and high total precipitable water content before the storm initiation (Fig. 3).

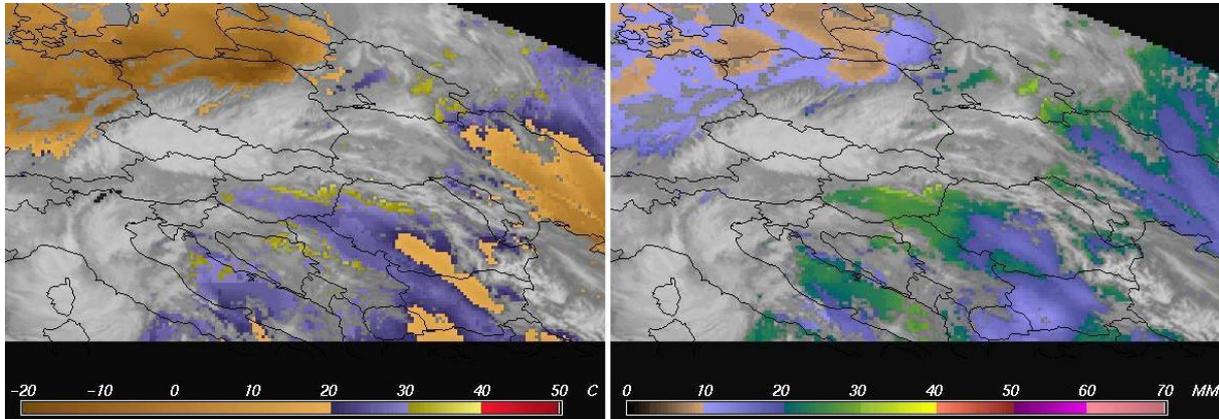


Figure 3: K index (left) and Total Precipitable Water (right) retrieved for 20 May 2008 09:00 UTC, courtesy to M. König (EUMETSAT).

## STRONG UPDRAFT

Fig. 4 shows a day microphysical RGB image visualized by the MSG\_RBG program of Lensky and Rosenfeld with two scatterplots: one over the convective region in Hungary and Serbia and another in Italy as a control area. These plots show statistics: IR10.8 brightness temperature ( $T_b$ ) versus effective radius ( $R_{eff}$ ) of the cloud top particles (calculated only for thick cloud pixels fulfilling some special criteria). The lines with different colour correspond to different percentiles. Steeper curves indicate smaller cloud top particles – i.e. stronger updraft. In the present case the plot over Hungary and Serbia shows that the region may be characterized by very severe updrafts. See the details in Rosenfeld and Lensky (1998, 2006).

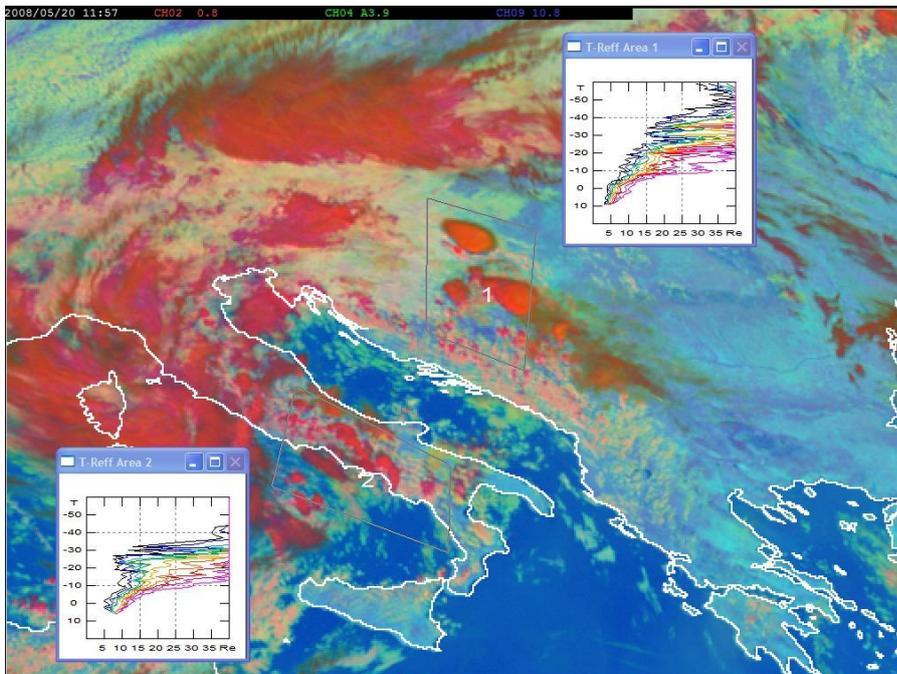
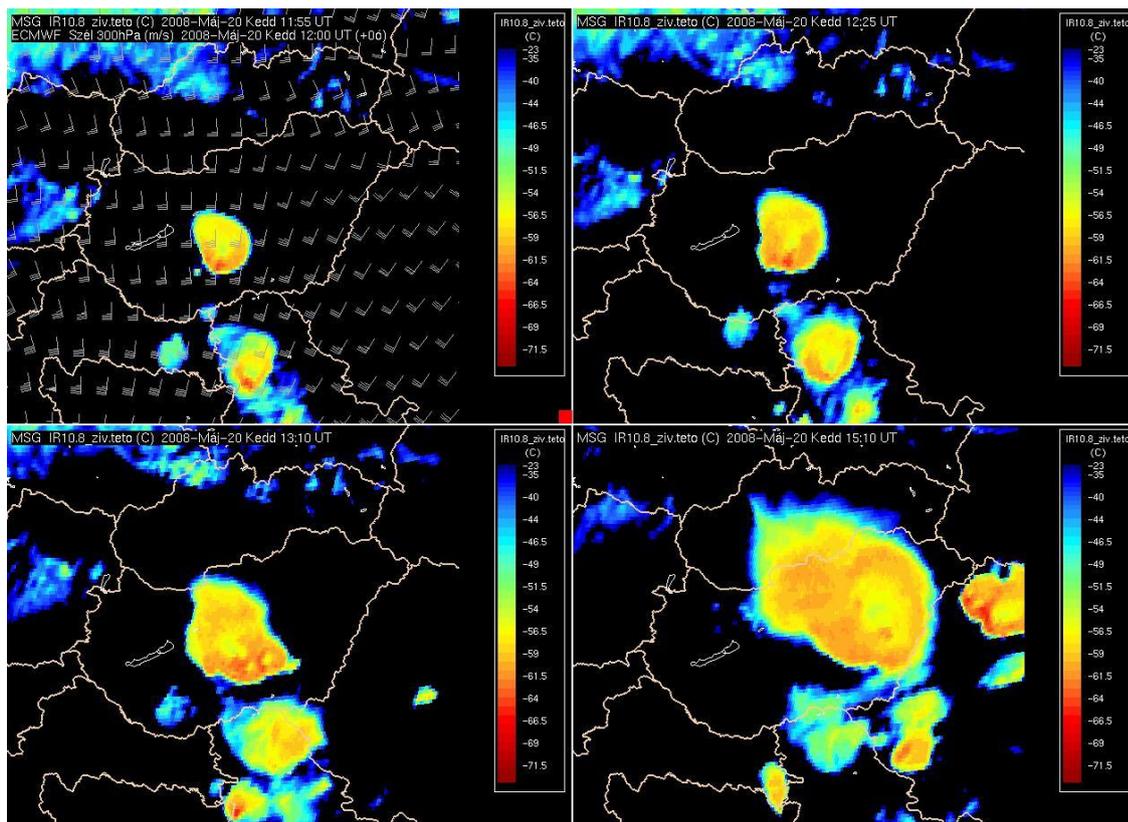


Figure 4: Met-8, day microphysical RGB image (VIS0.8, IR3.9refl, IR10.8) taken on 20.05.2008 at 11:55 UTC.

## CLOUD TOP FEATURES SEEN IN THE ENHANCED IR10.8 IMAGERY

For some storms/storm systems the IR10.8 brightness temperature distribution on the cloud top shows a 'cold ring' or 'cold U/V shape' (Fig. 5). According to USA statistics this feature is strongly related to the storm severity. Such storms often produce severe weather. For Europe there are not yet such statistics. However, several cases show that also in Europe cold ring shape is often related to severe weather underneath, like in the present situation.

To clearly see the features, the coldest brightness temperature range should be visualized at least in half-degree resolution. In Fig. 5 brightness temperatures are shown in colours for  $T_b < 240\text{K}$ , and black for  $T_b > 240\text{K}$ .



**Figure 5:** Meteosat 9, IR10.8 images taken on 20.05.2008 at 11:55 (upper left), 12:25 (upper right), 13:10 (bottom left) and 15:10 UTC (bottom right). ECMWF 300hPa wind is overlaid on the 11:55 UTC image (upper left).

One of the theories to explain the mechanism of the cold ring evolution is the so-called 'wake effect' (Heymsfield et al, 1983; Adler and Mack, 1986; Heymsfield and Blackmer, 1988). According to the wake effect the 'warm spots' form on the downwind side of the overshooting top. To check this we have overlaid the ECMWF 300hPa wind on the 11:55 UTC IR10.8 image, see the upper left part of the Fig. 5. That time the storm motion was low, so the wind is a good approximation for the storm relative wind. One can see that the warm spot had been formed really on the downwind side of the overshooting top, as the overshooting top is the coldest (reddest) part of the cloud (sometimes it may slightly shift to upwind direction).

## HRV CLOUD TOP FEATURES RELATED WITH POSSIBLE STORM SEVERITY

Strong and frequent overshooting tops often show strong updraft. Intense gravity waves, plumes (over anvil cirrus), radial cirrus may indicate strong updraft, possible severe nature of the storm (Setvak et al., 2003). In Fig. 6 overshooting tops can be seen, while in its right panel gravity waves, plume can be also noticed.

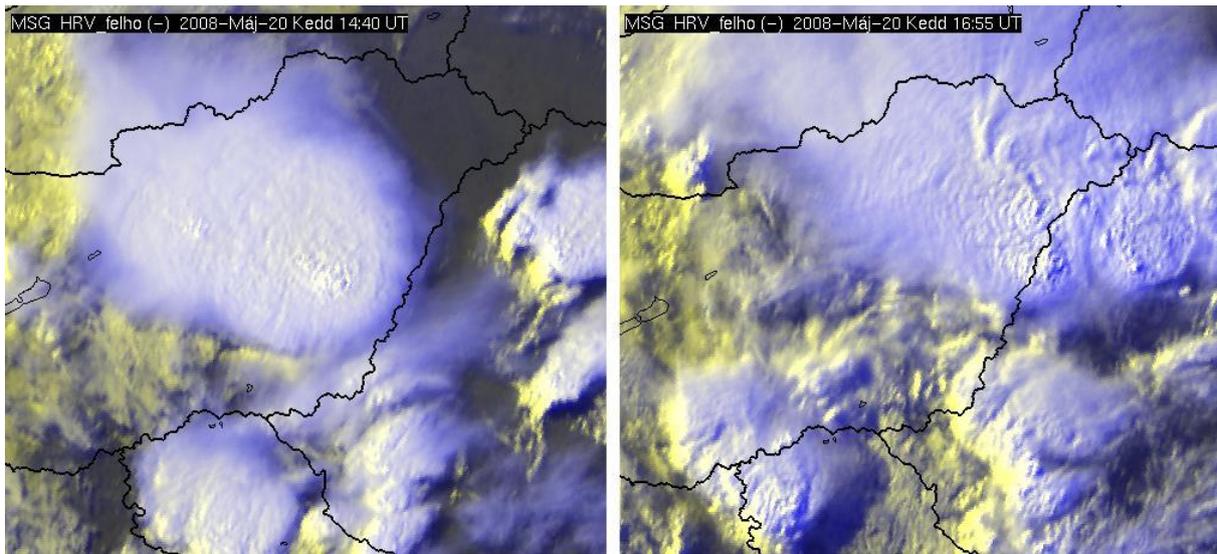


Figure 6: METEOSAT-9, HRV cloud RGB image (HRV,HRV,IR10.8) taken on 20.05.2008 at 14:40 (left) and 16:55 UTC (right).

### CLOUD TOP MICROPHYSICS

The presence of small ice crystals on the storm cloud top could be an indicator of storm severity (Lindsey et al., 2006). Small ice particles on the cloud top may partly be due to cells with strong updrafts. In strong updrafts the small water particles forming at the cloud base reach the cloud top quickly and have less time for interacting and growing (Kerkman et al., 2006; Lensky and Rosenfeld, 2006).

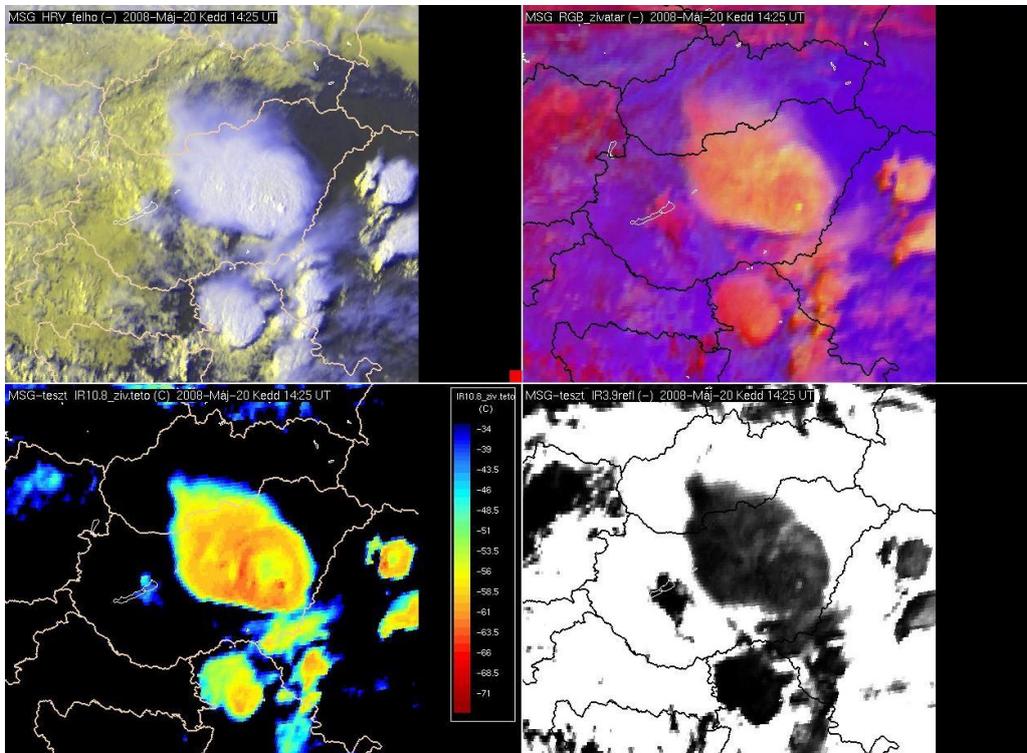


Figure 7: Meteosat 9 images taken on 20.05.2008 at 14:25 UTC. Upper left: HRV cloud RGB (HRV,HRV,IR10.8), upper right: convective storm RGB (WV6.2-WV7.3,IR3.9-IR10.8,NIR1.6-VIS0.6), bottom left: IR10.8 (Tb<240K), bottom right: IR3.9reflectance (R<9%).

The reflectivity in the 3.9 $\mu$ m channel (IR3.9refl) is sensitive to the cloud top effective particle size. IR3.9refl is low for ice particles, but relatively high for small ice particles. Fig 7 visualizes IR3.9refl in its lower right panel. It was calculated by the method of Rosenfeld and Lensky (1998). We used a range 1-9%, and a gamma correction with  $\Gamma=0.5$ . In the white area the reflectance is higher than 9%. The convective storm RGB image is presented in the upper right panel of Fig 7. Here the brightness temperature difference of IR3.9-IR10.8 (in green colour) is used instead of the calculated IR3.9 reflectivity. This difference strongly depends on the IR3.9refl. In this RGB the high-level ice cloud tops are reddish (opaque ice cloud with big particles), yellowish (opaque ice cloud with small particles) or rose (semitransparent ice clouds). In Fig. 7 the overshooting top can be seen both on the HRV\_cloud and IR10.8 image, as well as in the convective storm RGB as a yellow spot, and in IR3.9refl image as a white spot.

## LOW-LEVEL SEVERE THUNDERSTORM CHARACTERISTICS

In some cases on visible satellite imagery one may observe certain low-level features. Their appearances seem to coincide with the transition to, or intensification of severe thunderstorms (Weaver and Lindsey, 2003). These low-level severe thunderstorm characteristics are: flanking lines, feeder clouds, lines of towering Cu on the RFD region. In Fig. 8 the cloud patch to the south of the storm might be a flanking line and the other patches on the left might be the lines of towering Cu. The feeder clouds on the inflow part are not so well visible. Furthermore one can see some kind of low-level waves to the east of the storm, indicating that the wind must have been very strong.

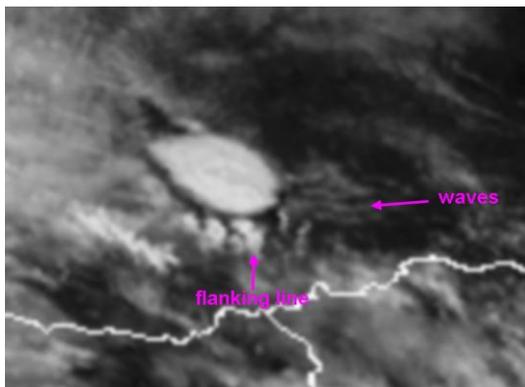


Figure 8: MET-8 HRV image taken on 20.05.2008 at 11:05UTC.

## SEVERE STORM CHARACTERISTICS ON RADAR IMAGES

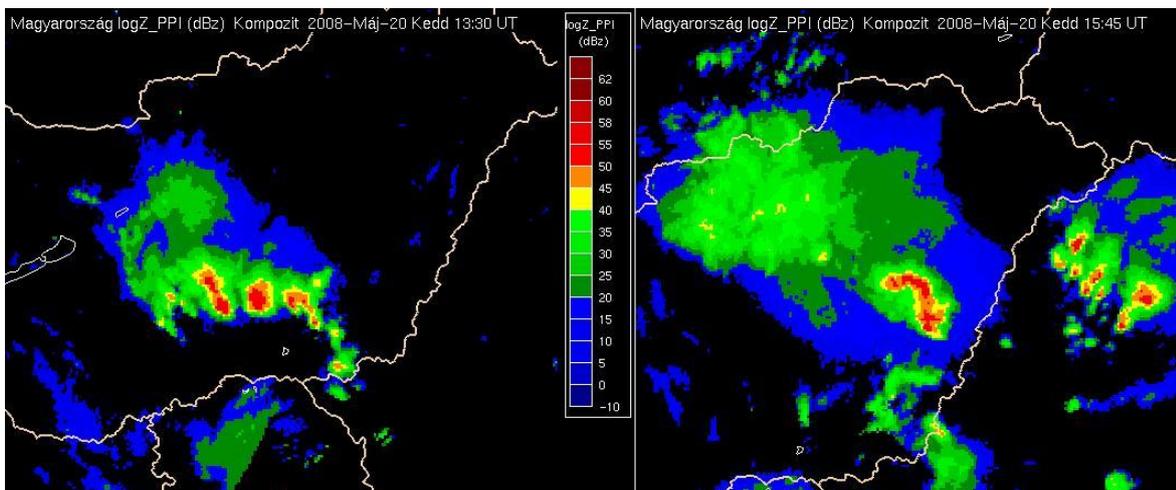


Figure 9: Radar image (Zmax, column maximum reflectivity) taken on 20 May 2008 at 13:30 UTC (left) and 15:45 UTC (right).

Fig. 9 presents radar images, showing columnar maximum reflectivity values. The left image shows three cells. A tornado was reported at the location of the middle storm cell. The eastern cell shows bow echo feature. The right panel shows also bow echo feature of the squall line. These radar echo features indicate the severe nature of the storm system.

## INVESTIGATING SATELLITE, RADAR AND LIGHTNING DATA

Radar and lightning data were overlaid on satellite imagery. High radar reflectivities (column maximum of  $Z > 35\text{dBz}$ ) were overlaid to see only the convective precipitation. The overshooting top shows the location of the top of the main updrafts, while the highest radar reflectivity spots show the location of the main downdrafts. Usually they are close to each other, as one can see in the following images.

The lightning activity was high. Around 1000 cloud-to-cloud (CC) and 100 cloud-to-ground (CG) flashes were detected every 10 minute in the most active lifecycle of the system. The location of the main group of the CC flashes is also expected to be close to the locations of overshooting tops and max radar echoes. However, the band of the flashes was broad and slightly shifted backwards (see Fig. 10). This can be connected to the transfer of the charges by MCS circulation. Note that there is some shift between satellite image and radar/lightning images due to the parallax effects.

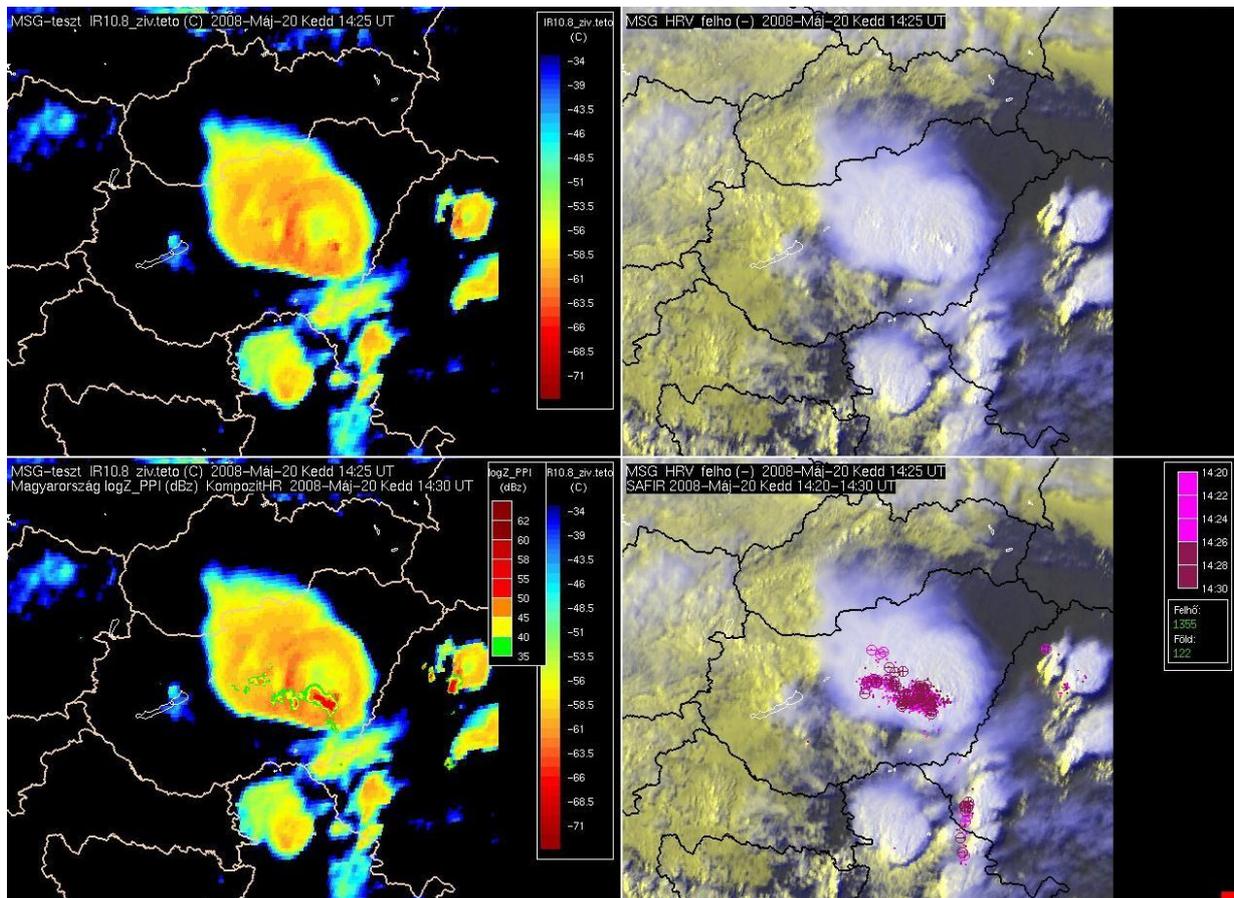


Figure 10: Meteosat 9 images taken on 20.05.2008 at 14:25 UTC. Upper left: IR10.8 image ( $T_b < 240\text{K}$ ), upper right: HRV cloud RGB image (HRV,HRV,IR10.8), bottom left: IR10.8 image overlaid by the radar image ( $Z_{\text{max}} > 35\text{dBz}$ ) and bottom right: HRV cloud RGB image overlaid by 10-minute lightning data.

## CONCLUSIONS

A case study was performed to investigate a tornadic thunderstorm, which occurred on 20 May 2008 over Hungary. The reported severe weather events were overlooked, the synoptic situation was

analysed. The paper is focused on remote sensing measurements. First we have analysed satellite and radar imagery separately; then satellite, radar and lightning data together.

In METEOSAT imagery we have analysed both the high-level cloud top characteristics, and the low-level features. The cloud top characteristics were analysed using several single channels and RGB images. We have found cold ring and cold U shapes in IR images; strong overshooting tops, plumes, radial cirrus, gravity waves in several visible images. We have investigated the cloud top microphysics as well: the effective radius of ice crystals on the storm top. Particle size was investigated qualitatively by visualizing two types of images, both being sensitive to it. These images present the particle size qualitatively through different colours. We have analysed the cloud top microphysics quantitatively as well through the calculated IR10.8 brightness temperatures and effective radius scatter plots. The imagery showed many small ice crystals on the cloud tops, and we have found steep scatter plot lines, both referring to high probability of strong updraft. By the analysis of the visible images at the early life cycle of the storm we have found some low-level features, which might also refer to the severe nature of the system: a cloud patch, which might be a flanking line and the other patches, which might be the lines of towering Cu. The spatial resolution of the image was not enough high to see the flanking line unambiguously.

In some radar images 'bow echo' feature were observed, which often indicates the severe nature of the storm or storm system. We have analysed together the satellite, radar and lightning data. We have visualized them together to see the relative locations of the different features.

In the 20 May case several remote sensing features were referring to the severe nature of the storm system. This case also shows that the analysis of the satellite images has complementary information to the nowcasting of severe weather. If other 'traditional' parameters indicate possible severe storm (high instability etc.) and the forecaster sees a cold-U or significant cold-ring on satellite imagery, he/she should be very cautious about the storm.

## ACKNOWLEDGEMENTS

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